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THE POTATO DISEASES OF MICHIGAN

BY

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SUMMARY AND GENERAL RULES FOR CONTROLLING POTATO DISEASES.

This bulletin gives a popular account of the diseases of the potato, Late Blight, Early Blight, Scab, Rhizoctonia, Dry Rot, Wet Rot, and Deep Scab, which are discussed under the general topics, Signs, Losses, and Control Measures. Dangerous diseases, as yet not reported from Michigan, are described.

To control Late Blight, Early Blight, and to secure stimulated growth of tops.

Use home-made Bordeaux mixture.*

Begin to spray when the tops are several inches above the ground, and continue to spray every 10 to 14 days throughout the growing season. In continued cold and wet weather, spray more often because of the danger of a Late Blight epidemic.

To control Potato Scab.

Soak clean, smooth, whole potatoes 1½ to 2 hours in formalin solution, made by using one pint of formalin to thirty gallons of water (1 oz. to 8 quarts). This treatment can be done at any time if care is taken to prevent reinfection. Plant on clean ground.

To control Rhizoctonia, Deep Scab, and Fusarium Wilt.

Know the signs of the common potato diseases.

The haphazard planting of potatoes from the cellar must stop.

Tubers should be dipped and then examined for Rhizoctonia, Deep Scab, and Scab, while still wet. All except clean, smooth tubers should be rejected. Cutting, if done by hand, allows sorting so as to rid the stock of cases of the Fusarium disease. A second disinfection, in formalin, if practised, should be of short duration.

*Dilute lime sulphur will not do as a substitute for Bordeaux mixture for potatoes.

THE POTATO DISEASES OF MICHIGAN.

BY G. H. COONS, RESEARCH ASSISTANT IN PLANT PATHOLOGY.

DISEASES CONTROLLED BY SPRAYING WITH BORDEAUX MIXTURE.

Late Blight of the Vine and Dry Rot of the Tubers.

This disease is caused by the fungus,* *Phytophthora infestans* (Mont.) DeBy. and is probably the worst disease of the potato. No disease of plants has caused so much money loss or so much human suffering. Given weather conditions favorable for its spread, it sweeps a whole country, reducing the potato crop materially. Fortunately, a general severe attack of this disease has not occurred every year in Michigan, and until 1912 it had been some time since the last epidemic of the Late Blight. This does not mean at all that the disease had disappeared, for each year some counties, in one part of the state or another, suffered from the disease. In the greater part of the state, however, the attack was so slight as to escape notice.

THE SIGNS OF LATE BLIGHT.

Late Blight of potatoes shows itself in two ways: first, as a blight of the parts above the ground, and second, as a rot of the tuber. Frequently, the type of rot found is "wet" rot, but this is, for the most part, a secondary trouble, following upon potatoes badly injured by Late Blight.

The first sign of the disease in the spring or early summer, as was shown in 1876 in the first careful investigation of the disease, occurs upon the young sprouts from a diseased tuber. This appears as the sprouts begin to grow after planting. The attack upon some seed tubers is often so strong, or the sprouts themselves so weak, that frequently no growth at all reaches the surface, and from others only a few spindling sprouts come up. These are soon covered with a white downy mass, the fruiting threads of the fungus. These diseased leaves and stalks are probably the starting point for the disease in the field. During cold, wet weather, the spores which are produced in great numbers, are spread from plant to plant by the brushing together of wet tops, the splashing of rain, etc., and a general infection results.

*A parasitic fungus is a plant which makes no food for itself, but steals its living from another plant, called the host. The vegetative part of the fungous parasite, i. e., the body, consists of threads which grow either upon or within the host, absorbing the food supply from the tissues. Fungi, for the most part, are spread by microscopic bodies called *spores*, which are produced in vast numbers. These bodies are either forcibly ejected a short distance and are then wafted by air currents, or are splashed about by rains. They serve the same purpose as do seeds for the higher plants.

The disease shows first as a brown spot surrounded by a semi-transparent, water-soaked border. This spot, by rapid advance of the organism, becomes much larger, and may involve an entire leaflet. With favorable conditions, the entire diseased area of the leaf becomes soft and blackened. The tissue is now entirely killed, and a field in this stage looks as if a frost had nipped it. The plant gives off a very strong, disagreeable odor; hence, the common belief among some men that they can tell when to spray, because they can "smell the blight." At the stage when the presence of the disease can be told in that way, the greater part of the damage is done.

On the under side of the diseased leaflet, the fruiting masses of the fungus appear and give this side a filmy or cobwebby appearance. Under cold, humid conditions the blighting of the tops continues until the entire vine is reduced to a blackened, rotted mass. It is this condition which cuts down a field so that a crop once of high promise looks as if struck by a killing frost. It is often the case that only this last stage of the attack is noticed by the growers—the scattered attack on the leaves usually escaping their attention. It is from such observers —men who go into the field with their spray outfits after all is over—that we hear the comment, "You cannot control the Blight."

ROTTING.

Contrary to the general belief, the rotting of the tubers is not caused by the fungus working down the stem, but comes about from the spores of the fungus which are washed or shaken from the leaves. These either get to the potatoes through the soil or are shaken upon the tubers in digging the crop; hence, the advice to wait a week or two, when weather and soil permit, after the blighting and death of the tops, before digging the tubers. The spores which reach the potato, sprout and penetrate the skin, or else gain entrance through wounds, and cause rotting. The first sign of the disease in the tuber is the slight brown discoloration just beneath the skin. This is present long before the potato takes on a sunken appearance. If the skin of the potato is scraped away, this brown condition is very evident. Following this, we have a shriveling of the potato, due to the progressive killing effect of the fungus and the drying which ensues. The potato becomes sunken in spots or "hobnailed," (Figs. 1 and 2). Very often the normal brown color of the skin becomes a more or less blue-gray or livid. If the potatoes are stored under moist conditions, they become covered with white tufts of the fungus. This stage is the same as that produced upon the leaves, and from these tufts the disease may spread in storage cellars to the other tubers. The final stage of this disease, as it shows on the tuber, is the "dry rot" stage. Here we have a hardened, worthless mass, about one-third the size of the original tuber.

WET ROT.

Frequently the destruction of the potato takes another turn. It seems that when a potato is weakened, or partly rotted by the Late Blight fungus, it easily rots, owing to the invasion of bacteria. This same condition follows other sorts of fungous attack, or it may come

Fig. 1. Rotting of tubers due to Late Blight.

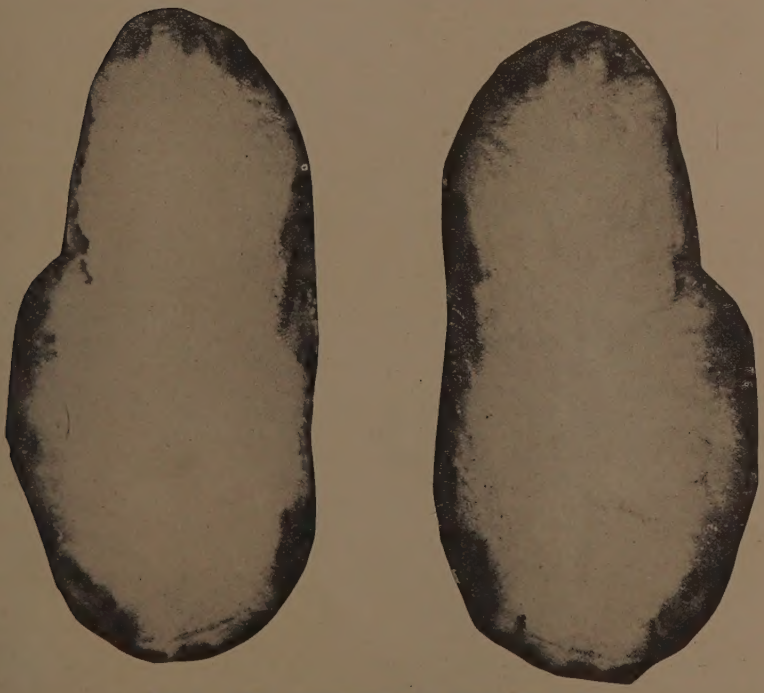

Fig. 2. Tuber, affected with Late Blight, cut in half.

from merely excessive moisture. From this we can understand the excessive loss by rotting in clay land, when the plants are struck by Late Blight. Along with this moisture relation on clay land, it must also be said that for some unexplained reason, sand filters out the spores to a much greater extent than clay, thus protecting the tubers. The fact that wet clay lands crack in drying, and thus expose the tubers, may also be of importance in this regard.

STORAGE.

The excessive rotting found in some storage cellars or in pits, where too little attention is paid to ventilation, shows that the moisture and temperature factors are important. To check rotting in storage, the cellar must be dry and cold—close to the freezing point. The use of lime is valuable only in that it aids in the taking up of the excess moisture; it does nothing, however, that ventilation will not do.

DISEASED SEED STOCK.

The disease is carried over in the seed tubers from year to year, and even in the driest years, there is probably a slight attack of Late Blight which remains unnoticed. Recently, a "resting" or winter stage has been discovered in cultures of the fungus, and while this stage has never been found in nature, it is still an open question whether this stage may not play an important role in starting the disease each year.

Two things point to the inadvisability of using, as seed stock, the product from fields injured by Blight. The most common source of the disease has been mentioned—it is carried to the field in the tubers. The second and more important point, one which has been amply shown by observation and experiment, is that the shoots from diseased seed are notorious for their weak and spindling growth. The practice of spreading rotted potatoes on the fields, as is done by many growers in the spring, is also to be condemned, since for a very little fertilizer value they are infesting their land with Scab and other diseases.

LOSS.

The losses caused by this fungus since its first outbreak are simply incalculable. In 1844 and 1845, the epidemic struck countries in Europe, notably Ireland, where the potato is the chief food, so severely as to cause national disasters. Periodically, closely associated with certain weather conditions, these vast epidemics have come. In some parts of the United States, some parts of Michigan, even, where the margin between favorable and unfavorable temperatures and rainfall is very small, these epidemics have been frequent. Fully one-third of the crop in Michigan was lost in 1885* and about twenty-five per cent of the crop of central Michigan was lost in 1889. One other general epidemic occurred a few years later, and other destructive epidemics occurred in 1902 and 1904, when the potato sections of Michigan, Wisconsin, and Minnesota were swept by Late Blight and Rot. The loss in 1912 was enormous, and practically all the large potato states suffered greatly. In some of the counties in this state the loss was almost a total one, due either to Late Blight or Rot, caused by this fungus.

*Spalding, V. M. and Smith, E. F., in Michigan Crop Report, Dec. 1, 1885.

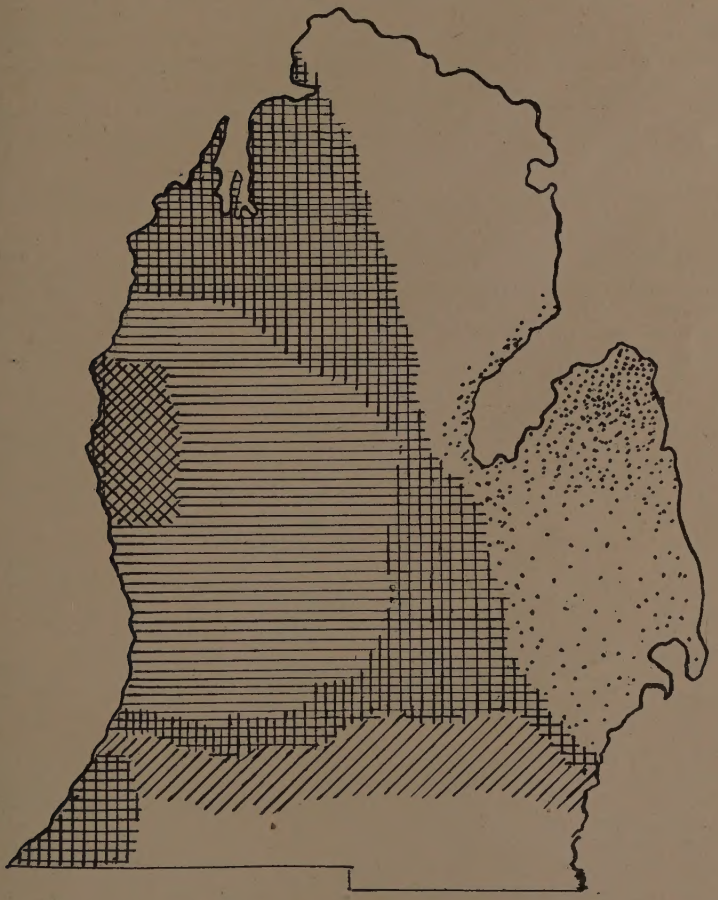

Fig. 3. Loss due to Late Blight and Rot for 1912.*

60-80 %

50 %

25-40 %

10-25 %

0-10 %

Slight shortage due to late Blight of vines, but excessive tuber rotting, varying from 10-90 %.

*Figures for the counties of the Upper Peninsula were not obtainable.

On the accompanying map, is shown the loss for practically all of the counties of the lower peninsula which were struck by the Late Blight epidemic of 1912. The data for this figure were obtained by correspondence with potato buyers, growers, and teachers of agriculture in the high schools.

Exact information as to such a loss is hard to obtain. Where, however, the shortage of the crop was considerable, or the rotting excessive, the figures are entirely dependable. Where a loss of from 10 to 25 per cent occurred, the correspondents differed, some reported much trouble, no doubt due to the nature of the land in the neighborhood, others reported absolutely no loss.

In estimating the 1912 loss from Late Blight, it is safe to say that, considering the state as a whole, about 20% of the crop was lost; but due to excessive rains, no doubt the total shrinkage of the possible yield was very near 25%. Twenty per cent of the crop means a loss from Late Blight of two to four million dollars. Where we take the loss per county, as furnished by correspondents, and, using the yield for 1909 as a basis, compute the bushels lost in the twenty-five leading potato counties of the state, we find for them alone an aggregate loss of 8,550,000 bushels. This great total, computed at 35 cents a bushel, gives a money loss of nearly $3,000,000. At best, this is a low estimate, because the price used is below the average price of potatoes for the season, and the yields on which these are based, and the acreage also, are a great deal below the corresponding figures for 1912.

When we consider that a potato crop showing from 60 to 90 per cent shortage or rot is not a crop that will pay commercially for the handling and sorting, and when we take into account the value of the labor spent in sorting and re-sorting the potatoes which rot in storage, we have another large addition to the total damage.

Unfortunately, many of the badly blighted potatoes serve as seed stock the next year. This again is a heavy toll on the crop, since the poor stands and the stunted plants will not help the yield of the following season.

Another, and the most insidious of the losses due to this disease, is the one borne by the consumer. In this day, when so much is being said about the high cost of living, this phase of the problem is of interest. In many localities, bumper crops were promised by the weather, and, in many cases, were harvested. A low price, but at the same time a fair one for the farmer, seemed assured. However, the prices, after a month, increased to considerably above the average price. The farmers' crop was short, the price rose, and a heavy loss, in the aggregate, was thrust on the consumer. Moreover, in districts struck by Late Blight and Rot, countless families laid in their supply of potatoes for the winter, only to throw them out in November. Here then is another form of loss.

From these different points of view, it seems safe to say that the loss for the state, which, at a most conservative estimate, would be put at two million dollars, would not be at all unfairly estimated, if placed at double this amount. This amount is large and is an absolute loss except insofar as it teaches potato growers a lesson and serves to focus attention on the scientific management of the crop.

CONTROL.

The control of this disease is considered under the general topic at the end of this section. Bordeaux mixture is an efficient remedy. Strong resistance has been noted in certain varieties of potatoes, and this opens up a promising line of experimental work, but, so far, recommendations cannot be made along this line until much more has been done.

Early Blight of Potatoes.

In 1888, B. T. Galloway, of the U. S. Department of Agriculture, noticed a disease of the leaves of potatoes, which was strikingly different from the effects produced by the Late Blight fungus described above. The first publication concerning the disease appeared in a farm paper in Australia, but confirmatory evidence was soon presented by various workers in the Experiment Stations in several states. Once attention was called to this matter, it was plain that there were several diseases affecting the leaves, which, although strikingly different from "Blight," were before this all grouped together as "Blight." Hence, the necessity for the other names for these diseases, and the application of the terms "Late" and "Early" Blight.

THE SIGNS OF THE DISEASE.

The characteristic signs of this disease are the circular, or nearly so, dead, brittle spots on the leaves. These spots vary in size from one-fourth to one-half inch or more. Each spot shows a series of concentric rings, "target-board markings." These rings, no doubt, mark the successive advances of the fungus and the killing of the tissues, which ensues. Several spots may run together and the edges of the leaves frequently show more spots than the centers. With an early attack, very often the dead spots drop out, due to brittleness and to the pulling away of the growing parts. This gives the leaf a "shot-hole" appearance.

The names of this and the preceding disease do not always seem appropriate, but as a general thing the attack of the Early Blight fungus *Alternaria solani* (E. & M.) J. & G., is early in the season, while the attack of the *Phytophthora infestans* (Mont.) DeBy. is much later.

THE EFFECT ON THE PLANT.

The fungus causing Early Blight does not cause a rot of the tubers, nor does it attack the stems directly. The effect on the leaves is noticeable, however, because of its stunting effect on the stems, and because of the effect on the yield. A severe attack on the leaves brings about an early death of the tops and the corresponding effect on the tubers is to produce "little potatoes," since the food materials stored in the tuber and the growth of the tuber itself, are dependent upon the vigor and length of life of the tops.

LOSS DUE TO EARLY BLIGHT.

The loss caused by this fungus-enemy has never been reckoned for Michigan, but it is safe to say that the yield of potatoes would be 25% larger than it is now on unsprayed fields, were this wasting disease controlled. It must be seen, however, that this type of loss, in most years, is quite different from that caused by Late Blight, since the latter takes its toll on the actual yield, while Early Blight keeps the yield from ever becoming a maximum one. In years when Late Blight and insects are not factors, this fungus is largely responsible for a yield of 100 bushels per acre in place of the 200 or 300 of which the soil is capable. In Wisconsin in 1906, the damage done by this fungus was estimated at $6,000,000, and the conditions in Wisconsin are not greatly unlike those of this state.

CONTROL OF LATE AND EARLY BLIGHT.

That the various diseases of the leaves and the serious rotting of the tubers due to Late Blight can be controlled to a great extent by spraying, is beyond all question. The standard spray, and the only one giving uniform success, is home-made Bordeaux mixture, and full directions for making this spray mixture are given on the last page of this bulletin. It may safely be said that following the introduction of this practice, more than twenty years ago, uniform success with its use has been obtained. In Vermont,* a summary of spraying experiments begun in 1891 and continued almost without interruption until 1911, showed an average increase of 105 bushels per acre of the sprayed rows over the unsprayed. In not a single year did the unsprayed rows equal the sprayed rows, the smallest difference being 18% in favor of the sprayed. In New York,† we have another series of experiments of similar nature. A ten year average from the experiment station fields at Geneva, N. Y. (clay loam soil), shows a gain of 69 bushels per acre from three sprayings, and a gain of 97½ bushels per acre from five to seven sprayings. These results, covering, as they do, long periods of time, show that the results from spraying are consistent, and that, in many cases, the gain is enormous.

Nor are figures to prove the case for Michigan lacking, although the experiments have not been continued year after year. These experiments fall into two groups: experiments done at the Experiment Station or under direct supervision of the Experiment Station; and those done by farmers following advice. Only the former results will be reported, although nearly every community has had spraying done by progressive farmers, which shows exactly the same beneficial effects.

Of the data at hand, the following figures are important:

In 1905,‡ on the College Farm, a field sprayed 6 times with Bordeaux showed a gain of 39.5 bushels over the unsprayed check.

In 1911, on the College Farm, a field was sprayed with Bordeaux mixture four times, while part was left unsprayed, as a check. The un-

*Lutman, B. F., 1911. Vt. Sta. Bul. 151, p. 247.
†Stewart, F. C., French, G. T., and Surrine, F. A., 1912. N. Y. Sta. Bul. (Geneva) 349.
‡McCue, C. A., Spraying for Potato Blight in 1905, 1906. Mich. Sta. Bul. 236, pp. 131-143.

sprayed portion yielded 80 bushels per acre, and the sprayed portion 119 bushels per acre.*

INCREASED YIELD DUE TO SPRAYING.

An interesting thing about the potato spraying is that the more thoroughly it is done, and the more frequent the sprayings, the better the disease control, and the greater the gain. Along with the increased yield from disease control, comes the remarkable fact that the Bordeaux mixture exerts a stimulating effect upon the foliage. To what this effect is due is not at all clear, but the fact remains that tops sprayed often with strong Bordeaux mixture are greener and produce material for larger crops than the unsprayed, even in years when diseases are not serious. From this it will be seen that there is a very good reason for the recommendation to spray every year, and it makes it very manifest that the spraying directed against these diseases is more than a protection, since it is a beneficial crop practice. It may well be called a form of crop insurance, where the premiums are all dividends.

General Rule for Summer Sprays.

Use Bordeaux mixture,† made at home, as described on the last page of this bulletin.

Begin to spray when the tops are several inches above the ground, and continue to spray every ten to fourteen days throughout the growing season. In continued cold, wet weather, spray oftener, because of the danger of a Late Blight epidemic.

While one or two sprayings may give protection against Early Blight, or if timely, may keep the tops alive in spite of Late Blight, safety lies in frequent sprayings. To obtain the largest crop, that is, to avoid minor injuries to the leaf, and to get the full stimulating effect of the Bordeaux mixture, the new growth of the tops must be kept covered.

To sum up, three things are necessary: Good Bordeaux, thorough sprayings and, most important, frequent sprayings.

DISEASES CONTROLLED BY SEED TREATMENT.*

Potato Scab.

There is probably no disease of potato so widespread or so well known as Potato Scab. Nor is there a disease of plants whose control measure is so well known among farmers. It can also be added that probably no beneficial crop practice is so widely neglected.

DESCRIPTION OF POTATO SCAB.

In the published descriptions of the disease, great vagueness exists on account of the presumption that the signs of the disease are familiar to all. But a comparison of the meager descriptions of the best informed

*Eustace, H. J., 1912, Potato Culture, Mich. Sta. Cir. 15, pp. 1-4.
†Dilute lime-sulphur will not do as a substitute for Bordeaux for potato.
‡Black Leg is also controlled by dipping sound potatoes.

writers on potato diseases and a study of the published cuts seems to indicate that at least two very different things are generally grouped together under this head. By Potato Scab, the author means the roughness or scurfiness of the skin of the tuber, usually about the lenticels, which is produced by an excessive cork production (Fig. 4). It is held by some that this excessive cork production is the response of the cells irritated or stimulated by the foreign cause. It is seen that the writer is disposed to consider deep pittings of the tuber different from the ordinary Potato Scab. These, however, are accompanied often by the

Fig. 4. Potato scab.

more superficial scab. This is the type of trouble usually called Deep Scab, and the author has never been able to find evidence from observations that this form of trouble is produced wholly by the scab organism.

DEEP SCAB.

From experiments performed at the Michigan Agricultural College, it seems safe to attribute Deep Scab (Fig. 7), largely to mites, and since this trouble is not controlled by seed treatment, as is the ordinary Scab, but is controlled by seed selection, the discussion is given under another head.

THE CAUSE OF THE POTATO SCAB.

In 1890, the production of Potato Scab by inoculations with a pure culture of a bacterial organism was reported. More conclusive work

was done later by R. L. Thaxter, of the Connecticut Experiment Station, and he was able to produce, upon growing potato tubers, what he considered to be typical scabs by inoculating with a pure culture of an organism, secured from scabby potatoes. He was able to find this organism in profusion on scabby potatoes in New England, and since then it has been demonstrated on scabby potatoes in the Middle West. Thaxter considered the organism a fungus of low organization, and he called it provisionally *Oospora scabies* Thaxter. Recent studies by Cunningham seem to indicate that the organism is one of the higher bacteria.

As a direct result of these discoveries, as to the probable cause of Potato Scab, came a discovery of the control measures to be employed. Instead of prejudice and supposition as to the nature of the trouble, it was seen that the trouble was due to a parasite, which, as experiments have shown, can live in the soil many years, and which, carried on the seed, can infest and produce a scabby crop on even the cleanest ground. Other crops, notably sugar beets, are said to be subject to the same disease; hence, there is another danger from infected ground.

LOSS CAUSED BY SCAB.

The loss caused by Potato Scab, and in this loss scabbiness of all sorts is included, is also very hard to estimate. It is, however, enormous. The potatoes sold from the wagons for storage in the cellars, are seldom clean and clear skinned. One can hardly find absolutely smooth potatoes served at the best hotels. Potato buyers find on an average one bushel of badly scabbed potatoes in a load of fifty bushels. These, of course, are thrown out at the car and the farmer loses there two per cent of his crop. Since the load represents potatoes that have been sorted in the field, more or less, and when we consider that the very scabby tuber is not picked up at all, it is clear that the extent of this disease is worthy of notice. Moreover, the sorting at the car is not at all severe, since a careful one, as would be done for fancy stock, would discard on the average from five to ten per cent of the crop. Many buyers pay five cents a bushel more for potatoes fairly free from scab than for the ordinary run of the fields. Here again we see the heavy loss the grower of scabby tubers must bear.

Many growers having good varieties would be in a position to furnish seed potatoes to their communities if they would control the Scab. It is true that scabby seed is sold, but more and more the farmer is learning that the grade of seed planted shows itself in the stand and in the crop.

THE SUCCESS OF SEED TREATMENT.

While Scab treatment is well known in Michigan, figures as to its efficiency were not at hand, and hence in 1912 a small experiment was performed to find the reduction of disease that could be obtained by the ordinary treatment. The following table is self-explanatory, and shows the percentages of scabby potatoes in the crop from treated and untreated seed stock.

TABLE I.

Treatment.	Total yield.	Average percentage of Scab.	Remarks.
Seed stock, scabby, untreated	78 potatoes	35.5 %	Many unmarketable.
Seed stock, scabby, untreated	115 potatoes		
Seed stock, scabby, dipped	158 potatoes	8 %	None unmarketable.
Seed stock, scabby, cut in pieces, then dipped	171 potatoes	8 %	Stand poor. Tubers small.
Seed stock, clean, untreated	131 potatoes	9 %	Some unmarketable.

General Rule for Scab Treatment.

Soak clean, smooth, *whole* potatoes 1½ to 2 hours in formalin* solution made by using one pint of formalin to thirty gallons of water (1 ounce to 8 quarts). This treatment can be done at any time, if care is taken to prevent reinfection. Plant in clean ground.

SOME CAUSES OF FAILURE IN TREATMENT.

Certain things influence the result. The character of the soil is important. Alkalinity of soils seems to favor the disease. Since the potato can be grown well on acid soils, the utilization of such soils is suggested by the U. S. Department of Agriculture. Aside from errors in treatment, failure comes from very unclean seed tubers, infected ground or reinfection of the tubers after dipping. This last may come from putting the tubers, after cutting, into the old infected sacks or baskets, covering them with infected material or from the dust of old bins, crates, etc. The sacks and crates to be used should either be new ones, or should also be soaked in the formalin solution. In a word, it must be remembered that the parasitic organisms which cause this disease are very minute, and are easily carried to the tubers. *Take great care that infection does not take place after treatment.*

Many farmers have failed to follow directions and have tried dipping the potatoes after cutting. Such a treatment frequently kills the seed tubers. That the treatment is unsafe has long been recognized. A few rows in the Plant Disease garden at the Experiment Station, on which treatment after cutting was tried in 1911, failed entirely to come up. A similar treatment, but for a shorter time, in 1912, gave a very poor stand. Desirable as it might seem as a method of avoiding reinfection of the tubers, it is dangerous. Moreover, many farmers do not realize that the formalin solution has a powerful effect on the tubers. It is not safe to increase the strength of the solution. A variation of one gallon, one way or the other, in the quantity of water, may not count, but there is not a large margin. The same is true of the length of time the potatoes are to be left in the solution. This should not be longer than 1½ to 2 hours. Experiments were tried in 1911, where, in one set, the time was doubled, but the ordinary strength of solution was used; and in another set, the time was as usual, but the strength of the solution doubled; both trials resulted in a very inferior stand.

*Commercial formalin is a 40% solution of formaldehyde gas in water.

DISEASES CONTROLLED BY SEED SELECTION.

Rhizoctonia, or Scurf.

The Rhizoctonia disease, or Scurf of potatoes in a disease of some importance in Michigan. It manifests itself by brown or purplish masses of fungous threads upon the tubers. The general effect produced is shown in the cut (Fig. 5). These lumps, (Fig. 6) ordinarily taken for dirt, clinging to the tuber, certainly detract from the appearance of the stock, and are indications, no doubt, of an attack upon other parts of the plant. Such lumps can be more easily seen when the potato is wet, and hence the suggestion under control measures.

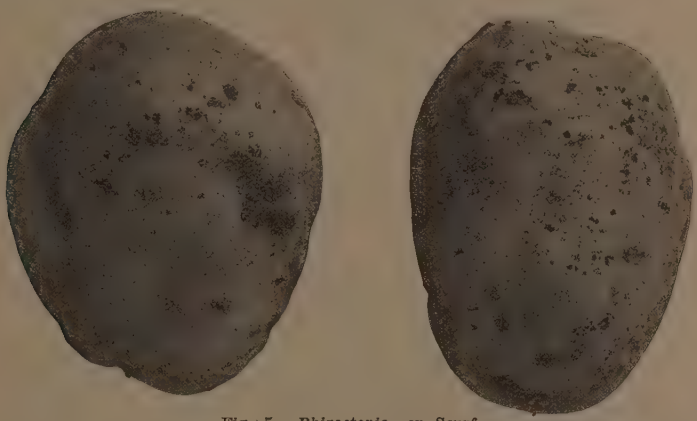

Fig. 5. Rhizoctonia, or Scurf.

In other states and in foreign countries, potato failures have been attributed to this fungus. It is believed that the form of the fungus seen upon the tubers is but a resting form, which carries the disease over from year to year. According to the work of many investigators the stems just beneath the ground are attacked and frequently girdled by this fungus.

The distribution of the fungus in this state is very wide and specimens have been obtained from many counties. Whether the disease produces a serious loss for Michigan is not known definitely, but at all events, it is dangerous and to be avoided, because of the possibility of loss. It is also of importance because of its effect on the quality of the tubers. Potatoes covered with these scurfy lumps can never be first-class. But for a third reason the disease is dangerous. Many other crops are attacked by Rhizoctonia diseases, and we are just beginning to realize the possibilities in this line. A large per cent of the "damping off" of young seedlings, such as sugar beets, results from an attack of this fungous group, and such a form of disease is common upon a great range of plants in fields, gardens, and greenhouses in Michigan. As yet,

due to difficulties in classification, the exact range of plants attacked is not known, but serious Rhizoctonia diseases have been reported on cabbage, sugar beet, carrot, lettuce, celery, radish, sweet potato, beans, alfalfa. There is, therefore, danger, (just how great cannot be said without further study), of allowing our fields to become infested with this parasite.

Fig. 6. Rhizoctonia, or Scurf, showing sclerotia upon the potato. Enlarged four times.

CONTROL.

Yet, with this evidence of wide distribution, it is not known whether the fields of Michigan are seriously infected with this organism or not. In the main, measures aimed at avoiding the disease are to be suggested. From experiments performed by the writer in 1912, it was shown that the *disease could be almost entirely avoided by planting clean seed.* Clean seed was obtained by a careful sorting of the potatoes before planting. From ten plots grown from this seed, the average per cent of Rhizoctonia present in the crop was 5.8%, the highest amount being 22%. Infected seed gave, as an average of three plots, 57% of diseased tubers.

TABLE II.—Rhizoctonia Disease.

Clean seed, average of 10 plots	5.8%
Infected seed, average of 3 plots	57%
Seed dipped in formalin	50%

Dipping in formalin, while beneficial for Scab, did not control Rhizoctonia, since seed tubers affected with the disease gave a crop showing 50% diseased, in spite of the treatment. For infected fields, nothing has been suggested in the line of treatment other than the application of

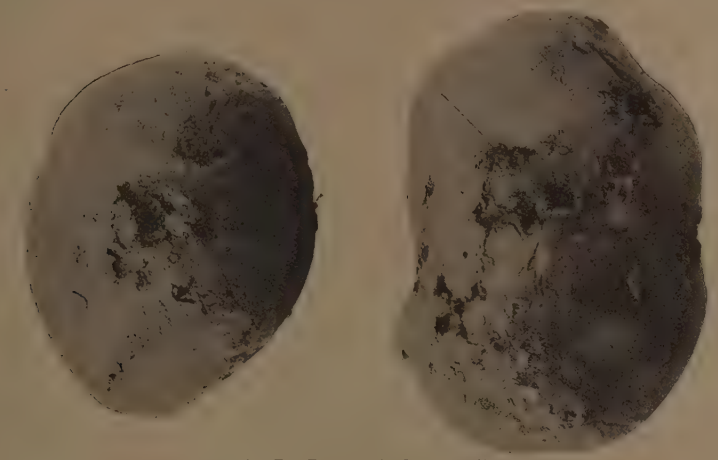

Fig. 7. Deep scab due to mites.

lime, and the value of this measure, so far as the disease is concerned, is very doubtful. It would surely have a bad effect on the amount of Scab prevalent. So far, no cereal crop has been reported as injured by this disease, and the use of these crops in infected fields may be recommended.

Deep Scab.

Along with tubers affected with the common form of Potato Scab, we find those which, while they may be scabby in part, are also deeply pitted (Fig. 7). Then, too, potatoes can be found which show smooth surfaces, except for one or two deep pits. It has been shown by the writer* that small spider-like animals, mites, (*Rhizoglyphus* sp.) are able to attack and make extensive pits and burrows in potatoes. So far as the observation has been carried, a large per cent of the Deep Scab of potatoes is due to these animals. Frequently their attack follows the common Scab, but, by experiments, the writer was able to secure typical pits and burrows by placing the mites on absolutely sound, young potatoes. Within a week, the dozen or so mites on each potato had made

*Cf. Appel and Börner, 1905, Arb. a, d, b, Abt. 4.

many deep holes, very similar to those found in the field. This form of trouble is important, and the potatoes so attacked are a greater loss than those attacked by the Scab. Frequently a large per cent of the crop is diseased by Deep Scab. The writer observed a case in Nebraska, where the owner, anxious to increase the amount of a new variety, had planted the entire crop each year without sorting, and in this crop, after the third year, there was by actual count, 100% of Deep Scab. The accompanying cut shows something of the proportion of Deep Scab which may be found in potatoes sold for seed (Fig. 8). Data as to loss are, of course obscured by the fact that this disease and the Scab are confused, but it is safe to say that Deep Scab causes at least as much loss as the other form of scabbiness.

Fig. 8. Two bushels of ordinary "seed" potatoes sorted into piles to show proportions of sound and affected tubers. 1, with Rhizoctonia; 2, with Scab; 3, with Deep Scab; 4, clean.

CONTROL.

Reference has been made to the fact that sometimes Potato Scab is not controlled by the ordinary dipping methods. To what extent the confusion between these forms of scab is responsible for the failure can only be surmised, but it is probable that this has been a factor in the experiments. In tests made at the Experiment Station, the mites were not injured by a two hours' immersion in the formalin solution used for Scab treatment, or in a 1 to 1,000 corrosive sublimate. In an experiment done in triplicate, potatoes affected with Deep Scab were planted untreated, as checks, and similar potatoes were dipped as usual. There was no noticeable decrease in the amount of Deep Scab due to the treatment. Clean potatoes were planted as a part of this experiment and almost a complete freedom from Deep Scab resulted. This result points to the easiest method of handling this disease. Only potatoes free from scabbiness and pitting should be selected for seed. It may also be

pointed out here, that, in general, all advice given by station workers upon the control of Potato Scab has emphasized the point that clean, smooth seed tubers should be selected, and it seems evident that in this way the practice suggested by the writer has already been employed, though unwittingly. It is worthy of note that, in the experiments upon the control of the Potato Scab, which have been reported, the most conflicting results have been those in which "very" scabby seed has been planted.

Dry Rot of Potatoes.

Growers have recognized, for a long time, two types of rotting—wet rot and dry rot. In the one case, the potato becomes a soft, slimy, ill-

Fig. 9. Dry rot due to a Fusarium.

smelling hull, filled with a ropy, liquid mass. This is a rot caused by bacteria, and is largely a secondary rot, following severe attacks of Late Blight, or is brought about by very damp or warm conditions of the soil or storage cellar. Dry rot is brought about by several fungi, and aside from *Phytophthora infestans* (Mont.) DeBy. several species of *Fusarium* are largely responsible. Potatoes affected with dry rot become wizened and hardened. The dry rot may involve the whole tuber or only a portion. With dry rot, caused by the Late Blight fungus, and in some forms of dry rot, caused by a Fusarium, the skin of the tuber becomes a gray or bluish color. Frequently the tuber is covered with white tufted growths—the fruiting threads of the fungus which has caused the rot, (Fig. 9). Those examined in 1912 were almost all due to

Late Blight fungus. But examinations of rotted tubers other years have shown the presence of Fusarium. Such tubers are unfit for seed.

The Fusarium Wilt of Potato.

SIGNS AND EFFECTS ON THE PLANT.

In 1904, Erwin F. Smith and D. B. Swingle called attention to the fact that a fungus called by them *Fusarium oxysporium* Schlecht. caused a dry rot of the potato. Attention had been previously called to the first signs of this dry rot, the blackening of the bundles so that when a small slice was cut from the stem end of a potato, a brownish or black ring was evident. (Fig. 10). Smith and Swingle noticed that this

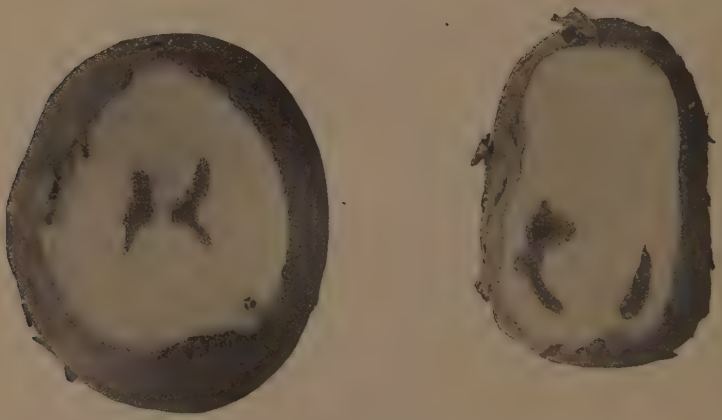

Fig. 10. Cut stem end of a potato affected with Fusarium Wilt.

blackening was found to progress in storage and cause black streaks extending along the water tubes until one-half or one-third of the potato was involved. The next stage, believed by them to be due to this fungus, was a gradual invasion of the tissue surrounding the bundles along with a drying and wizening of the tuber. Frequently bacteria and other species of *Fusarium,* came in as secondary rot agencies, and produced either a wet or dry rot, depending on conditions of storage.

The effect of this fungus-enemy, as shown by Smith and Swingle, is not limited to the tuber, but it works in the vascular system of the plant, producing a gradual wilting. This begins, usually, with the lower leaves which turn yellow; then comes a rolling and curling of the leaves, upward and inward. Potatoes affected with this disease die early. This effect of the disease is, in the opinion of the writer, probably the most important in producing a loss. The growing season, on the average, is shortened a week or two, and a crop of small sized tubers is produced. These mature more or less, but the yield from fields so diseased cannot be a maximum one.

A CONFUSING CONDITION.

The diagnosis of this disease is rendered difficult by the fact that the water tubes of the tuber may be more or less browned or yellowed for a depth of 1/16 or 1/8 of an inch, in the absence of this disease. The cause of this is not known. The distinction of this sign from that of Fusarium Wilt was first pointed out by Prof. L. R. Jones, who noted that this trouble did not increase in storage, nor did cutting off the browned portions result in any improvement of seed stock. Cultures made by the writer in Nebraska in the summer of 1910, and continued at the Michigan Agricultural College, have given results indicating the absence of fungi.

Blocks of the browned water tubes, taken after washing the tubers in mercury bichloride, followed by rinsing in sterile water, and taken after cutting a thin slice from the tuber with a sterile knife, gave, in every case, when placed in plates of media, bacteria, but no fungi. Work done at Michigan Agricultural College with potatoes showing similar conditions gave similar results. In experiments where the stem ends were cut off and the sound end planted, no improvement in the crop resulted.

Since a browning or yellowing may be present in from 80% to 100% of the seed tubers, and since it seems to prejudice unjustly buyers and farmers requiring seed, the author believes it very important to note that there is this form of vascular discoloration which may be mistaken for Fusarium Wilt but which is probably of a different nature.

In the main, it seems safe to consider Fusarium Wilt only in those cases of browned water tubes which show considerable depth of penetration. This penetration increases in storage and produces more than a general yellowing or discoloration of the water tube system. The writer has noted that with Fusarium Wilt, a noticeable shrinkage of tissue, at the point of attachment to the tuber stem, is very evident, even at digging time, and in cases of attack of Fusarium, the author thinks this sign of value for diagnosis.

CONTROL.

This disease is carried over for the most part in the seed, but experiments by Manns* in Ohio indicate that the disease can be carried in the soil and that, from such a source it is much more virulent than from cultures. Manns believes that when a soil is infected with the fungus, other crops besides potatoes and tomatoes would best be used in the rotation for a space of five or six years. Manns is the only writer offering decisive control measures for this disease, and by them he has reduced the amount of infection in the tubers from 76 to less than 17%. Along with this decrease in the amount of tuber infection, he secured, in nearly every case, marked increase in the yield. The treatment was simple, consisting of cutting off all diseased parts of tubers and subsequent disinfection. This treatment, in cases where infection of tubers is shallow and where clean ground is available, is well worth practising. It merely requires close sorting of the seed, knowledge of signs of

*Manns, T. F., 1911. Ohio Sta. Bul., 229.

Fusarium trouble, and examination of the cut end of each potato. Badly infected tubers should be rejected. Disinfection is secured by a treatment with formalin as for Scab, but for a much shorter time.

General Rule for Tuber Selection.

It is first of all important that the grower know the signs of the common potato diseases. The figures show these plainly. The haphazard planting of potatoes from the cellar must stop. Tubers should be dipped in formalin and then be examined for Rhizoctonia, or Scurf, Scab, Deep Scab, and Late Blight (See Figs. 1 and 2), while still wet. All except clean, smooth tubers should be rejected. Cutting, if done by hand, allows sorting so as to rid the stock of the cases of the Fusarium disease. A second disinfection, if practiced, should be of very short duration.

DISEASES NOT YET REPORTED OR NOT WIDESPREAD IN MICHIGAN BUT WHICH NEED BE FEARED.*

The Wart Disease of Potatoes.

Very recently, the U. S. Department of Agriculture has been given authority to establish a quarantine against the importation in foreign commerce or transportation in interstate commerce of such plants as seem likely to lead to the introduction or establishment of new or dangerous diseases. The first plants to be placed on the proscribed list were the five-leaved pines (on account of White Pine Blister Rust) and the potato, because of danger of importing the Wart Disease. The signs of this disease are shown in the accompanying cut (Fig. 11). The badly diseased potatoes are entirely replaced by a white, warty mass, giving off a very unpleasant odor. This is the stage in which the spores are being set free into the soil. A mildly-attacked tuber may have only one or two eyes affected. In very mild cases, the affected eyes are grayish, then turn brown, and then finally turn black. In somewhat more pronounced cases, small dark warts are produced at the diseased eyes, and all gradations are found from such tubers to those that are entirely destroyed. When once established in a field, it is very persistent, and the only safe procedure is to abandon the use of that field for potatoes for a good many years—just how long has not been determined. Tubers from such a field should never be used for seed, even when apparently healthy. The disease has obtained a foothold in Newfoundland, but apparently does not occur elsewhere in America, notwithstanding the large shipments of potatoes from abroad, which, in some years, have amounted to millions of bushels. The fact that the importation was largely for food purposes probably explains the absence in the United States, as yet, of the disease. However, it is highly im-

*Prepared by Dr. E. A. Bessey.

Fig. 11. The Wart disease of potato. From U. S. Dept. of Agriculture.

portant that the disease be watched for, and if found, be reported at once to the nearest Experiment Station, lest it become a destructive pest. Now that the National Quarantine Act is in operation, the danger of the importation of the disease is far less than previously.

Curly Dwarf Disease.

This disease is characterized by a curling downward of the main axis of the leaves and a crumpled appearance of the leaflets, due to the fact that the growth of the veins does not keep pace with the growth of the tissue between. No tubers are formed, or those that are produced are small, and the plants are dwarfed. Since the preparation of this bulletin Curly Dwarf has been reported from Montcalm county by Mr. C. W. Crum. While no specimens have been received the signs of this disease are so characteristic that there can be little doubt of its presence. Dwarfed plants should be destroyed and the little potatoes from affected hills should not be used as seed stock.

Leaf Roll Disease.

This disease is distinguished from the preceding one by the fact that the leaflets curl upward. The leaves are usually yellow or purplish, and the plant may be somewhat dwarfed. Quite characteristic of the disease is the fact that the mother tuber usually remains intact for a long while. Such tubers as are formed, are usually small, and do not contain as much starch as normal tubers. Aerial tubers are often produced. Tubers from the diseased plants, even if but slightly affected, will transmit the disease, and the growth from such tubers will be badly affected.

Both Curly Dwarf and Leaf Roll have been observed in the United States, and have been quite destructive where found. They are probably not widespread in Michigan. Like the Wart Disease, they can be guarded against to a large extent by taking seed from fields in which no signs of the disease are apparent.

Black Leg.

Black Leg is a bacterial disease of potato which as yet has been found only in one locality in the state (Upper Peninsula). This disease is readily recognized by the very characteristic coal-black sore or lesion which is produced on the stem, at or near the surface of the soil and extending some inches along it to the seed piece. (Fig. 12). The diseased plants are more or less unthrifty. The tops of the plants are more compact, and the young leaves curl and fold along the midrib. Yellowing and death of the tops follow. The tubers frequently rot. In cases of light attack, the tubers remain small. This disease is very prevalent in certain localities in Maine and occurs sporadically in other parts of the country, where Maine seed has been introduced. The dis-

Fig. 12. Black leg of potato. (Maine Sta. Bul.)

ease is carried in decaying, bruised or cracked potatoes. W. J. Morse of the Maine Experiment Station has shown that this disease can be readily exterminated from fields, by planting sound seed which has been disinfected as described for Scab.

Powdery Scab.

Fig. 13. The Powdery Scab of Potato (tuber from Canada).

Recently another disease has been found rather widely spread in Canada and so far has been found in several states. In gross appearance it is somewhat like the ordinary scab, but as the names, Powdery or Corky scab indicate, it is more of a pustular outgrowth than the scurfiness ordinarily found. (Fig. 13). The Department of Botany wishes to obtain specimens of scabby potatoes from all parts of Michigan in order to find if this disease has been introduced.

Reference is made to these diseases in spite of their not having been found in Michigan, in order that growers may be on the lookout for

them, and report them at the first appearance. Since the first preparation of this manuscript in March, 1913, two diseases, Black Leg and Curly Dwarf, have been reported. Some of the others may be here—a comprehensive survey of the state has not as yet been made—but at least they are not widespread.

THE POTATO SITUATION IN MICHIGAN.

Michigan ranks first as a potato state. In growing the mammoth crop of nearly 40,000,000 bushels, too large an acreage is used, the yield per acre is far below the possible yield. There is no surer way to increase the yield per acre than to practice the extensively-tested control measures here outlined. Furthermore if Michigan potatoes are to hold their place in the market, the crop must be clean. If the enormous loss of 1912 is not to appear periodically, frequent sprayings with Bordeaux mixture must become as much of a crop practice as planting or harvesting. As yet Michigan is not getting full price for the crop. Until fancy stock is grown for the best trade, and until Michigan potatoes enter into the seed trade, the larger returns will not come.

Mr. W. A. Orton of the U. S. Department of Agriculture has described the quality of seed stock desired by the seed trade of the various sections. He points out that varietal purity and certain types of tubers are wanted. He also indicates the degree of freedom from disease which is necessary and the assurance which the seed trade is about to demand as to that freedom. In short, the seed trade, of the South, especially, wants potatoes which are certified by the proper State authorities as free from certain diseases. To furnish and protect such certification the inspection, by a trained pathologist, of the growing fields is necessary. The expense of such certification should be borne by the grower.

This plan is very feasible for Michigan. With the seed trade clamoring for a trustworthy product at almost any price and with Michigan as yet not badly infested with such diseases as Fusarium Wilt, Rhizoctonia, or Black Leg, it would seem that the opportunity is great.

BORDEAUX MIXTURE.*

Bordeaux mixture is made of copper sulphate, lime and water. It is, practically a mixture of a 2% solution by weight, of copper sulphate and a 2% solution of lime.

The preparation is usually four to six pounds of copper sulphate, with about the same amount of lime, to fifty gallons of water. Poison, ½ pound Paris Green, or 2 pounds Arsenate of Lead, or one quart of the stock solution of Kedzie mixture is added to 50 gallons of Bordeaux when "bugs" threaten. The copper sulphate will readily dissolve in two gallons of hot water, to which should be added enough water to make twenty-five gallons or one-half barrel. Do not use an iron or tin vessel to dissolve this in, as the copper sulphate will destroy it, and besides the iron will spoil the Bordeaux. A wooden pail is good. Slake the lime into a thin paste and add water to make twenty-five gallons. Pour,† or let these run together into a third barrel, and the Bordeaux is made. When it is emptied into the spray barrel or tank, it should be strained through a brass wire strainer to catch any of the coarse particles.

Whenever it is necessary to use a quantity of the mixture, it is desirable to have the lime and the copper sulphate in "stock solutions." A quantity of lime is slaked to a paste and held so by being covered with water. The copper sulphate, say fifty pounds, is placed in a clean gunny sack and suspended in a barrel (one with wooden hoops is much to be preferred) containing twenty-five gallons of water. This will dissolve in about a day. One gallon of this "stock solution"‡ is equal to two pounds of copper sulphate.

A good quick way to combine these three substances is as follows: Put the amount of the "stock solution" of copper sulphate required in a barrel, and add enough water to make 25 gallons, or one-half barrel. Put about 7 pounds of the lime paste in a barrel and add 25 gallons of water, making a thin whitewash. Pour, or let these two run together into a third barrel, or directly into the spray barrel or tank, being sure to strain. When partly run in, test with ferro-cyanide of potash§ to make sure enough lime has been used. If Paris Green, arsenate of lead, or any other poison is to be used, make it into a thin paste with a little water and add it to the Bordeaux mixture, which is now ready to be used.

*Adapted from Eustace, H. J., and Pettit, R. H. Spray and Practice Outline for Fruit Growers, 1913. Mich. Sta. Special Bul. 61.

†Efficient agitation or stirring is an essential to good Bordeaux.

water will be enough for a season. Drop a very little in the Bordeaux, if a reddish brown

‡Always stir this "stock solution" before dipping any out, in order that what is used may be full strength.

§This chemical can be secured of any druggist. Ten cents worth dissolved in a pint of water will be enough for a season. Drop a very little in the Bordeau, if a reddish brown color appears more lime must be added. If there is no discoloration, there is enough lime. Ferro-cyanide of potash is extremely poisonous, so observe great care in its use.

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5 Forecasts of Frosts.
8 Planting Sugar Beets.
10 Sugar Beets.
11 Frozen Trees and their Treatment.
20 Report of the Upper Peninsula Sub-station for Years 1901 and 1902.
21 Cheese Problems.
28 Report of the Upper Peninsula Sub-station for the year 1903.
29 Additional Work upon the Associative Action of Bacteria in the Souring of Milk and in Other Milk Fermentations.
33 Extended Studies of the Associative Action of Bacteria in the Souring of Milk.
41 Report of the Upper Peninsula Sub-station for Years 1905 and 1906.
42 Bacterial Associations in the Souring of Milk.
46 Report of the South Haven Sub-station for 1907.
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